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AERIAL SURVEY HANDBOOK

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FOREST SERVICE

AERIAL SURVEY HANDBOOK

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U. S. FOREST SERVICE

AERIAL SURVEY HANDBOOK

It is the purpose of this handbook, first, to acquaint the Regional Offices with the general approved Forest Service contract and specifications for securing aerial photographs which are to be used on extensive mapping projects, and, second, to outline in brief form the general procedure to be followed in compiling administrative or other planimetric maps from the photographs so contracted or from aerial pictures secured from any other source for mapping purposes.

Any unusual topographic character of the area to be mapped; any unusual control conditions or any special map requirements may be sufficient reasons for a departure in the minor details as hereinafter set forth but the basic principles of control requirements, the definite relation of the flight direction to the control net and the radial line work, should be adhered to under all circumstances.

1. ESSENTIALS OF CONTRACTED PHOTOGRAPHS

It is desirable that all vertical photographic work be done with standard single lens aerial mapping cameras equipped with lenses using a cone of not less than 8 1/4 inch focal length. Lenses having focal lengths less than 8 1/4 inches have too wide an angle,

(over)

and cause great distortion and displacement in the finished photographs. For purely cartographic work the so-called multiple lens rectified photographs are satisfactory, but where the photographs are to serve for any administrative purpose afterwards, the single lens photographs are more desirable.

It is most desirable to have the work done from an altitude as high as conditions will economically permit in order to reduce the displacement of objects to a minimum and to reduce the number of photographic exposures. It is ideal, when possible, to specify pictures on a contact scale of approximately 2000 feet per inch which means that the flying elevation should be about 16,500 feet above the general average elevation of the area to be mapped. This of course is impossible in sections of the country high above sea level or having extreme conditions of relief, so special consideration must be given to such areas when specifying the photographic scale.

2. PERTINENT FACTS TO BE PREDETERMINED

On the best available small scale map or maps, the area to be photographed should be outlined; all known and existing control, such as triangulation stations in and around the area and traverse lines which meet the requirements specified in the "Ground Control" Section of this handbook should be, as accurately as possible, indicated on this same map.

With these data it will then be possible to lay out the most economical control system and determine the method to be used.

(See "Ground Control Section".) In this connection the most satisfactory in the "Traverse Control Method" and has been most commonly used by the Forest Service. Plane table triangulation can be successfully used, however, especially in areas topographically suited for such work and where the inaccessibility for traverse control and its identification presents a serious problem.

Assuming that the control to be extended would be by the "Traverse Control Method", except under very adverse conditions which would call for special study and planning, this discussion of contracting for photographs will deal primarily with the photographic requirements for the "Traverse Control Method". The intricate work of utilizing "Plane Table Control" will necessarily follow after the photographs have been secured.

Using the "Traverse Control Method" it is desirable to predetermine the economic location, accessibility and approximate length of the necessary traverse lines. It should be borne in mind that the photographic strips should be controlled as near the stereoscopically covered ends as practicable and by lines running in a general direction at right angles to, or across the flight lines.

When the ends of the strips are to be a considerable distance apart or, in other words, when the strips are quite long, it will be necessary to extend intervening traverse control lines across the strips so as to make the distance between those control lines no less than that specified as standard by the U. S. Geological

Survey, i.e. "control must be carried around the edge of each quadrangle and once across its center, east and west". For maps compiled on the scale of 2000 feet per inch but for latter reduction and publication on the scale of one inch equals one mile, these traverse lines should be no more than approximately nine miles apart north and south, and fourteen miles east and west.

When the control system or net has been definitely decided, it should then be possible to determine and specify the direction of the flight lines. These should run parallel to each other and as nearly at right angles to the general direction of the control lines as possible; at least the flight lines must cross the proposed control lines. It is recommended that the whole set-up be so planned that the flight lines will run north and south if possible. In some instances these control lines might have to be extended beyond the limits of the areas to be mapped, due to some unusual topographic conditions or in order to reach a closing station or line. In the event that some of the control would necessarily have to extend beyond the limits of the project boundary it is important that the method and system of control be considered and planned in advance of writing a contract, to make sure that the photographs requested will extend over and include the entire proposed control net.

The foregoing essentials having been determined it would then be possible to prepare and furnish "Project Boundary" Maps to be attached to the contract. In outlining the area to be

photographed care should be taken, regardless of control influences, not to "skimp" or outline the area too close to the project limits. The pictures requested should extend at least one or two miles beyond the project boundary on all sides and far enough beyond the contemplated control lines to secure complete stereoscopic coverage when those lines lie outside the boundary itself.

The proposed control lines should also be indicated on the map and these should be photographed separately as specified in the sample contract. This should be done primarily as a safeguard against any trouble developing in the radial line work due to bad control conditions which might arise later in the procedure. By photographing the area along the proposed lines of control it will be possible to lay these strips by radial line methods, (see Radial Line Procedure) in such a manner that there will be developed, on the map and along with the control, a wealth of very rigid radial points which will materially strengthen the entire mapping job.

A study of the attached contract and specifications which have been approved by the Committee on Specifications of the American Society of Photogrammetry will show that all other details and requirements are self-explanatory and need not be discussed further. The part of the specifications designated "Oblique Photographs" is non-essential and for ordinary mapping projects need not be included. Such oblique photographs are secured for pictorial purposes only.

It is desirable to require the contractor to submit weekly reports giving daily weather conditions, air hours and showing the area covered by photographs. This not only serves as a check on the progress of the photographic work but also provides a means of showing in what areas the field and office work can be initiated to obtain the best co-ordination of the steps of procedure. Due to an urgent need of the photographs to initiate the mapping work, in some instances it might be very desirable to arrange partial deliveries of photographs as they are taken. This will necessitate close co-operation between the contractor and the responsible parties in charge of the mapping project. In such cases the contractor's weekly progress reports are essential. A sample form of a typical Forest Service "Aerial Project Report" is attached.

The photographs and material delivered by the contractor should be carefully inspected and checked against all requirements and specifications before acceptance.

AERIAL PROJECT REPORT

U.S.D.A. No. 560

ABRAMS AERIAL SURVEY CORPORATION

Lansing, Michigan

WEEK ENDING_____1935

UNITS A-B-C

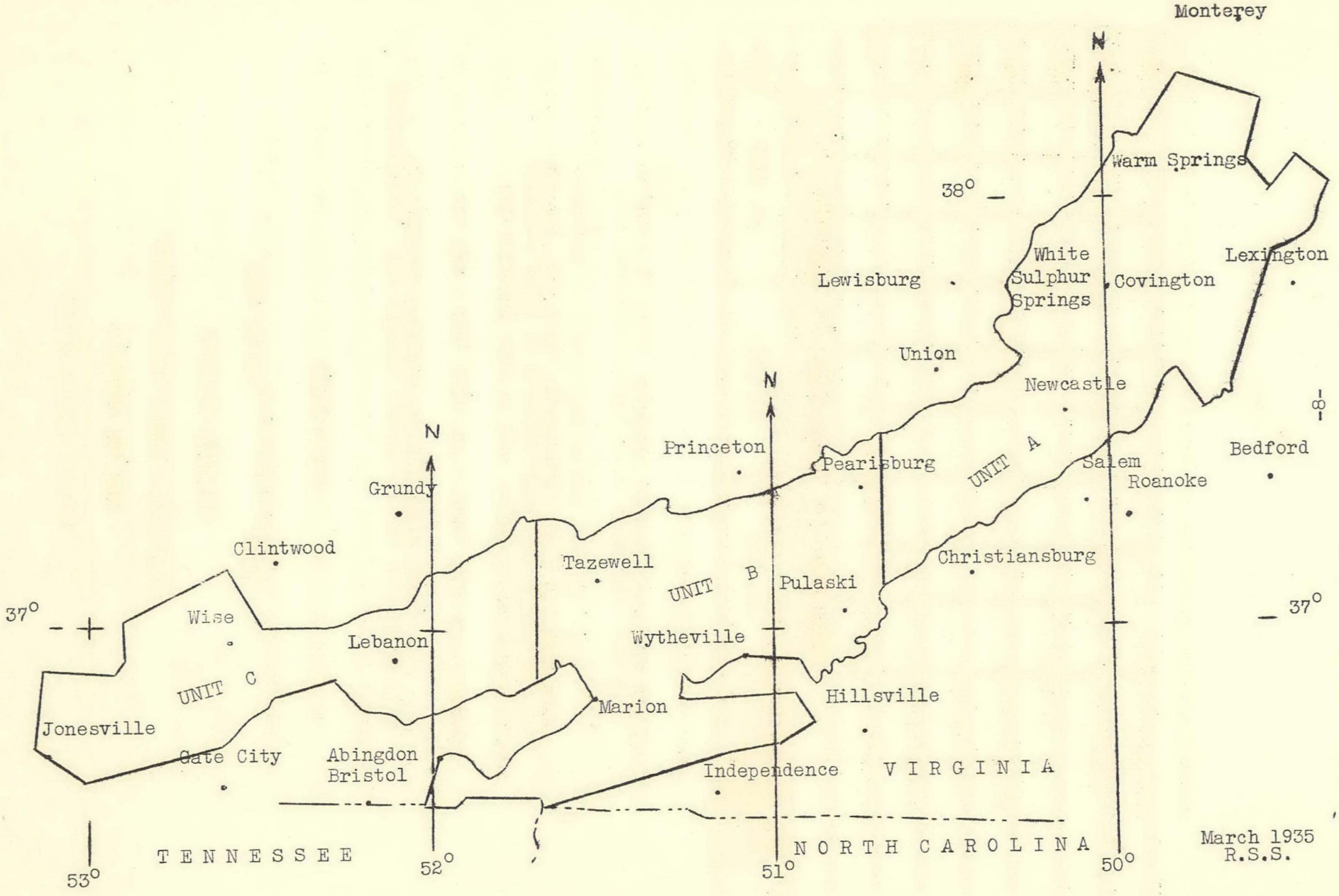
Instructions: Use colored pencils on map on reverse side to indicate portions flown on each Unit.

Unit "A" - Red, Unit "B" - Blue, Unit "C" - Green

The original copy of this report to be mailed every Saturday night to Regional Engineer, Forest Service, 724 9th St., N.W., Washington, D.C., and duplicate furnished to Forest Supervisor, Roanoke, Va.

Each submitted report to be cumulative and show progress to date. Hatchure area delivered in final form.

DATE	UNIT "A"			UNIT "B"			UNIT "C"			WEATHER	MATERIAL DELIVERED TO DATE
	Strip No.	Air Hours Taxi	Photo	Strip No.	Air Hours Taxi	Photo	Strip No.	Air Hours Taxi	Photo		
Sun.											
Mon.											
Tues.											
Wed.											
Thur.											
Fri.											
Sat.											


Monterey
N
Warm Springs
38°
White Sulphur Springs
Lexington
Lewisburg
Covington
Union
Newcastle
N
N
Princeton
Pearisburg
UNIT A
Salem
Bedford
Roanoke
Grundy
Clintwood
Tazewell
UNIT B
Pulaski
Christiansburg
37°
Wise
Lebanon
Wytheville
37°
UNIT C
Marion
Hillsville
Jonesville
Gate City
Abingdon
Bristol
Independence
VIRGINIA
TENNESSEE
NORTH CAROLINA
53°
52°
51°
50°
March 1935
R.S.S.

GROUND CONTROL

FOR

AERIAL MAPPING

The control necessary to properly execute the mapping of an area with aerial photographs depends largely upon the requirements of the final product. For the purpose of administrative mapping in old Forests or new areas, the Forest Service is desirous of standardizing its procedure, methods and results so as to utilize as much of its past field control work, as well as the control of other government agencies that might have monumented ground records in or near the areas to be mapped. In order to do this, it is of course necessary to base all field work upon true geographic position, and to execute all map compiling on a polyconic projection of identical datum. Note: All projections should be on North American 1927 datum if available.

3. FIELD ACTIVITY PRIOR TO PHOTOGRAPHIC WORK

It is most important that as much of the control as possible be marked in the field so as to be identifiable on the photographs after they have been taken. In order to be sure of positive recovery of the vital or "key" points of control it has been found that prior to any photographic work all basic triangulation stations within the area to be photographed as well as all "key" plane table triangulation points (if plane table triangulation control is to be used) should be marked on the ground in such a manner

as to definitely register on the photographs when taken. For this purpose, satisfactory results have been obtained by using the station or point as the center and marking a line circle, 50 feet in diameter and four to five feet in width, completely around the point. This of course can only be done in accessible places. For points difficult to reach with three or four sacks of lime, white hunting or cheese cloth securely fastened to the ground on all sides and in the shape of a cross with its center at the station or point, is suggested.

In this connection it is most desirable to mark a few well identified G.L.O. corners. The corners so marked should be scattered throughout the area and just enough of them marked as are necessary to control the land net.

4. TRIANGULATION

The basic triangulation work for aerial mapping is the same as that required in other Forest Service work and is detailed in other manuals of instruction used by the Service.

5. PLANE TABLE TRIANGULATION

In sections of the country where the topography and forest cover permits, it is economical and satisfactory to use plane-table triangulation nets which have been initiated or developed from a basic triangulation net. Great consideration should be given, however, upon planning and contemplating such control, to the fact that this work is primarily for the purpose of initiating the photographic radial line work, and the problems involved in that procedure

should be thoroughly understood and anticipated before resorting to plane table triangulation as a means of picture control. See "Radial Line Work." It is very likely that plane table control will have to be supplemented by stub traverse lines (same degree of accuracy as set forth under "Traverse Control Method") extending from the "cut in" points out at right angles (as nearly as possible) to the direction of flight. These stub lines should be located and run so as to tie in the best strategically located and most easily identifiable picture points available.

6. TRAVERSE CONTROL METHOD

Horizontal traverse control for aerial mapping, conforming to the prescribed standards, should be obtained from distances measured on the ground with a steel tape; a record being made of azimuths or bearings measured with a transit at each bend in the line. Such control should begin and end at points whose geographic positions have been previously determined. Stellar observations should be used for determining azimuths; preference being given to Polaris at eastern or western elongation as this is the simplest and most accurate method. Stellar observations should be taken at about ten or fifteen mile intervals on long lines or at least every fifty stations (set-ups). Solar observations should be used intermediately on such lines as a check on azimuth and to give proper adjustment from sustained azimuth to true azimuth. The proper azimuth adjustment on lines running in a general east or west direction is most important in order to satisfactorily "close" the

lines on points of known geographic position and enable them to be plotted on a polyconic projection.

The principal traverse lines on which the entire aerial survey map depends for its accuracy in horizontal position, shall be executed with such precision that the error in any distance shall not exceed 1:5000 i.e., 1.04 feet per mile. It is essential that this permissible error not allow for compensating "errors of closure" but require that each and every line must be within that degree of accuracy. This necessitates that frequent intermediate solar or stellar observations be taken in order to properly adjust to true azimuth as mentioned before.

On short stub lines, stellar or solar observations should be taken at each terminus.

These requirements appear rather stringent for ordinary tape and transit traverse but as a result of the experience the Service has gained in measuring over 4000 miles of transit traverse for picture control, it has been conclusively demonstrated that a stadia check is not sufficiently accurate to eliminate or discover small or accumulative errors, consequently it is cheaper and more satisfactory to have a "follow up" or second set of chainmen independently measure each line. The mean of their two measurements is accepted as the correct distance providing they agree within the permissible error. Otherwise, one set of chainmen must remeasure the questionable line. Complete instructions for the extension of this work are found in U.S.G.S. Bulletin

788, beginning on page 89.

Too much emphasis cannot be placed on the necessity of securing accuracy in the control work. This does not mean an accuracy beyond what is required, but the abolition of all errors and mistakes. The initiation and accuracy of the aerial triangulation work is dependent entirely on the ground control work and aerial triangulation can unknowingly be extended from poor work. If it should be, it will necessarily culminate in chaotic results and necessitate the correction of the field work before the aerial triangulation work can be compiled.

Under ideally coordinated conditions the engineer on the ground, when extending control (either "Plane Table" or "Traverse") for vertical photographs, should have with him prints of the aerial photographs of the area in which he is working. It is then possible for him to identify and designate on the photographs, also to definitely tie-in with his survey, all the necessary "picture control points" for later initiation of radial line work. The ability to accurately plot on a polyconic projection, these identified "picture control points" is the prime object of the whole control scheme. Therefore these points must be located with the same degree of accuracy as the main traverse.

The picture control points may be identifiable points on the traverse itself, but these points, if possible, should be so selected as to form an equilateral triangle within the stereoscopic overlap of two pictures, and should be as far apart

as the overlapped area will permit. One point should preferably be somewhere on the right hand side of the principal point (center) of the photograph and one on the opposite side, and both should be as far distant therefrom as the photograph will permit. At some convenient location along the control lines the involved pictures of each strip (stereoscopically covering the controlled area) should be so controlled. For physical reasons and sometimes because the side-lap of the adjacent parallel strip is more than liberal it will not be practical nor economical to control every strip in this exact manner, but some identifiable points should be tied-in on all strips. Picture control points so identified and tied-in along the control on the parallel flights, are also identifiable on the control flights, thus making them most rigid and secure. This supplements the control with strong radial points which will prove invaluable for initiating radial line work on other strips.

It will not be likely in all cases that the photographs will be available for use at the time the control is being executed in the field; in fact it is probable, in most instances, that the control will be executed prior to the procurement of the photographs. In this event, it will necessitate a return to the area after the photographs are available, to identify on the pictures, and tie-in to the control, all the necessary "picture control points".

At the time the control is being run in the field every effort should be made to accurately tie-in all known and existing G.L.O. corners which lie in the immediate vicinity of the lines of control. This is the easiest way to definitely establish the geographic relationship of the G.L.O. land net to the mapping projection.

The true interpretation of a photograph is a difficult matter. In general, features which form regular lines on aerial photographs are easily interpreted; of such are railroads, highways, roads, trails, streams and shore lines. Houses, various buildings; swamps and other features partly concealed by timber are difficult to clearly identify, and much more satisfactory results will be obtained if these can be interpreted in the field. Absolutely correct identification of picture control points is one of the most important steps in aerial mapping. Therefore a clear and unmistakable identification of these points, by one who can properly interpret photographs stereoscopically, is very essential.

7. OFFICE PROCEDURE

Upon delivery of all photographic material by the contractor, if such material has been contracted, the name of the Forest should be stamped on the reverse side of each photograph. All material should be carefully checked for complete compliance with specifications, especially regarding longitudinal and side lap, crab, coverage of designated areas, delivery of all material, etc. All omissions or deficiencies should be noted and the contractor advised immediately

so that steps can be taken to correct them before acceptance of the contract as complete.

Some of the materials not commonly used in ordinary map compilation but more or less essential for the method of radial line work, are large sheets of transparent cellulose-acetate or celluloid, polished on one side and frosted on the other. The most convenient size of these sheets is 40" x 50" and sufficient should be available to completely cover, on the compilation scale, the entire area to be mapped. These can be purchased for approximately $1.50 each. After proper seasoning (hanging freely in the air for a week or 10 days) a polyconic projection on the compilation scale should be carefully laid out and inked, on the frosted side of the sheets. These, then constitute the base upon which the radial line and map compilation work should be done. The celluloid sheets are subject to scale changes due to atmospheric conditions, especially humidity and for extensive mapping projects it is recommended that the projection and control be plotted on metal mounted sheets from which the projection lines and all control can be traced onto the celluloid sheets at one time under similar atmospheric conditions. This is the most satisfactory method of maintaining a record of true map scale and maintaining a consistent scale on the celluloid base sheets. These metal mounted sheets can be maintained as a permanent record of the original mapping work, in fact, they serve as an excellent base for all subsequent compilation work. It might be found desirable to transfer the planimetric map detail to these

sheets afterwards from the celluloid sheets. · Metal double mounted sheets 42" x 60" can be purchased for approximately $15.00 per sheet. Care should be taken to allow for a small amount of lap of one celluloid sheet upon the other, when several sheets are necessary to cover the area.

On the celluloid base sheets, all control points, identified picture control points and all G.L.O. corners that have been tied to the traverse or plane table control, should be plotted according to their true geographic position.

The involved G.L.O. township and section line net (chronologically reversed) showing all topographic and cultural ties along the section lines should then be compiled on the celluloid sheets in accordance with the geographically located G.L.O. corners. These salient topographic features, so tied and plotted, constitute a valuable supplement to the control and will afford a visible means of checking the final map compilation.

8. RADIAL LINE WORK

From this point forward, a knowledge of photogrammetry is essential to properly understand and execute the necessary steps of radial line work and map compilation. Ability, skill, resourcefulness, and considerable experience are the prime personal requisites for execution of such work.

Preparatory to the initiation of radial control, all principal points should be stereoscopically transferred from each of the photographs to the adjacent photographs and designated by 1/8"

diameter blue circles. (The following color legend is suggested merely as a matter of consistency.)

All identified control-points and picture control-points should be transferred from the field photographs to the office photographs and these points should be designated by 1/4" diameter yellow circles (diluted yellow show card paint.) The station name or number should be shown along-side.

All radial control points should be chosen stereoscopically; and not less than three, nor more than four points, should be located on each side of the principal point and approximately on line across the photograph normal (right angle) or nearly so, to the line of flight. This will provide each photograph with 18 to 24 "three cut" radial control points. These points should be designated by 1/4" diameter red inked circles. All points so chosen and designated should be transferred to all other lapping photographs along the line of flight and on the adjacent overlapping strips. A few of the radial points so transferred from, or to, an adjacent strip (tie-points) should be designated by showing the adjacent photograph number along-side.

Each photograph should then be turned face down and centrally placed on a celluloid templet. (These templets are 8" x 10" clear, transparent, light weight cellulose-acetate celluloid and one should be provided for each photograph). The photograph so placed should be firmly fastened along the entire edge to the templet with scotch tape.

All radial lines should be then carefully drawn on the templet. Radial lines drawn to control points, picture control points, identified G.L.O. corners and radial tie-points should be so designated on the templet. The principal point of the photograph should be designated by a small black inked circle with the photograph number along-side. A fine dashed line should be drawn from the principal point to all other principal points which fall on the same photograph. (Incorrect or careless placement or drafting of radial lines is the most prolific source of error and therefore these lines must be carefully drawn with a finely set ruling-pen using black India ink.)

The templets should be stripped from the photographs, and the graphic triangulation is extended with them directly on the assembled celluloid base sheets. The templets of the "control strips" should be laid first and so laid as to maintain "picture azimuth" from principal point to principal point; at the same time giving sharp and distinct radial line intersections on all plotted and identified picture control-points and thereby creating or developing the definite positions of all other radial control points, within the strip, on the celluloid base. These and all other templets should be securely and individually fastened to the celluloid base by means of small pieces of scotch tape at the corners or sides and allowed to remain there until all templets have been laid. From the laid strips of control templets, the templets of the other photographs can be likewise put down in their relatively true positions

utilizing the radial points of the control strips as tie-points, thereby supplementing the plotted control.

Too much emphasis cannot be placed on the fact that, throughout the whole templet-laying procedure, "picture azimuth" from principal point to principal point must be maintained (excessive tilt in the photographs causes exceptions) and sharp well defined intersections must be maintained on all plotted and identified picture control points, all lime-marked G.L.O. corners, all radial points and all common or strip tie-points.

When all templets have been satisfactorily laid and fastened onto a group of assembled celluloid base sheets, a seasoned vellum overlay for each base sheet should be placed and secured over the corresponding base sheet and templets; all principal and all intersection points as well as the minute line intersections of the polyconic projection, should be registered with some distinctive and recognizable symbols on the vellum overlay. Care should be taken to show the photograph numbers alongside the corresponding principal points.

9. TOPOGRAPHIC COMPILATION

In the area immediately around its center and within the limits of the average stereoscopic coverage between successive photographs in the same strip and each adjacent picture, all drainage, roads, trails, railroads, buildings and structures and other pertinent topographic features should be definitely indicated (freehand) with colored ink (red suggested) directly on each photo-

graph with the aid of the stereoscope. Care should be taken not to duplicate on adjacent or overlapping photographs, the indicated features already outlined on one photograph.

For mapping projects in areas of moderate relief where the photographs have been reasonably consistent to map compilation scale it would ordinarily be possible to trace all topography directly from the photographs onto the celluloid base sheets by graphic adjustment to the radial points, providing the base sheets have all principal and intersection points registered upon them. This can be done by fastening the celluloid sheets and the templets very securely into position and turning the whole assembly over; then registering the principal points and radial points on the reverse side of the celluloid.

The most satisfactory and most accurate method, however, is to compile all topographic features directly on the vellum overlay, in pencil, using single line symbols, with the aid of a "Reflecting Projector". This "Reflecting Projector" as designed by Regions 7 and 9 is an instrument which projects the photographic image directly on the vellum and it is so adjustable that displacement of detail and the variation in scale on the photographs are immediately compensated. Therefore the topographic compilation becomes a simple process of tracing the images of the essential topographic features that are adjusted to the registration of the principal points and all intersection points. The use of an instrument of this nature is practically essential in a country of much relief.

Copies of the plans and specifications of the "Reflecting Projector" can be had upon request and can be easily built under contract at very small expense, (probably $150 to $200.00 including the lens). In the event a composite bid can be prepared for all Regions a better price might be secured in Washington.

When all required topography, culture, etc., have been recorded on the vellum overlay, it should then be placed beneath its corresponding celluloid base (registering by the minute lines) and is ready for the final drafting of all such details on the frosted side of the celluloid base. All data on the celluloid sheets should be shown in conventional symbols with India ink, otherwise photographic reproductions could not be made. To prevent the ink from scaling from the celluloid, mix gum arabic with the ink in such an amount that an inked line when dry appears dull-black rather than glossy. There is a special celluloid ink now available which has been found excellent. It is known as "Craftint" and can be secured from the Craftint Manufacturing Company, 210 St. Clair Avenue, N.W., Cleveland, Ohio. To further accomplish adherence, shield off all of the sheet except the part in immediate use and keep the sheet absolutely clean and free from grease by rubbing the part to be inked with a cloth dipped in carbon tetrachloride. As a matter of record the principal point of each photograph should be shown by a 1/2 inch diameter black circle with the photograph number alongside at least 1/4 inch high.

Upon completion of the celluloid base maps showing all pertinent topographic and cultural features, the land net, polyconic

projection and picture centers, they should then be shipped, in a suitable galvanized metal map-can, to Washington for photographic reproduction to the desired administrative map scale.

Standard specifications for single lens photographs are now being prepared by a sub-committee on specifications of the American Society of Photogrammetry and when approved and accepted by the Committee will be probably adopted as standard by all the federal mapping agencies. These specifications will probably be available by September 15 at which time they will be incorporated in this Handbook and additional copies furnished you. They should be carefully studied and used in preparing any future specifications for single-lens photographs.

For handy references and for more detailed description of some of the principles involved in this procedure, the following bulletins may be secured and will prove useful.

"Training Regulations" #190-27 - U. S. Army Air Corp.

Bulletin #788 - U.S.G.S.

M & P Factor Tables - U.S.G.S.

Higher Surveying, Vol. II - Breed & Hosmer -
Fourth Edition, 1934.

Topographical Survey Bulletin #62 - Dept. Interior -
Dominion of Canada.

For the adaption of this procedure to its particular mapping needs, the Forest Service acknowledges with due credit, the influence of the comprehensive instructions set forth in the "Acquisition Survey Handbook" compiled by Region 7. The principles and procedure as outlined in that handbook have been an indispensible guide in the compilation of this "Aerial Survey Handbook."

FOREST SERVICE
Southwestern Forest & Range Exp. Sta.
TUCSON, ARIZONA
DEC 2 - 1935
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